Research Proposal for the use of Neutron Science Facilities

LANSCE
Los Alamos Neutron Science Center

☐ Fast Access ☐ Joint CINT Proposal

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Submission Number: S1523
Date Received: 03/14/11

Program Advisory Subcommittee: Nuclear Technology
Focus Area:

Flight Path/Instrument: 4FP60R / GEANIE
Estimated Beam Time (days): 14
Days Recommended: 0
Dates Desired:
Impossible Dates:

TITLE
Development of Neutron-Induced Gamma-Ray Reference Cross Sections

☒ Continuation of Proposal #: 20091553
☐ Ph.D Thesis for:

Principal Investigator: Nelson, Ronald O
Institution: Los Alamos National Laboratory
Citizenship: United States of America
Phone: 505-667-7107 **FAX:**
Email: rnelson@lanl.gov,ronelson99@gmail.com
Local Contact: Devlin, Matthew

Co-Proposers	Institution	Citizenship	E-mail Address
Devlin, Matthew	Los Alamos National Laboratory	United States of Am	devlin@lanl.gov
Fotiadis, Nikolaos	Los Alamos National Laboratory	United States of Am	fotia@lanl.gov

RESEARCH AREA

- ☐ Biological and Life Science
- ☐ Chemistry
- ☐ National Security
- ☐ Earth Sciences
- ☐ Engineering
- ☐ Environmental Sciences
- ☒ Nuc. Physics/chemistry
- ☐ Astrophysics
- ☐ Few Body Physics
- ☐ Fund. Physics
- ☐ Elec. Device Testing
- ☐ Dosimetry/Med/Bio
- ☐ Earth/Space Sciences
- ☐ Materials Properties/Test
- ☐ Other:
- ☐ Mat'l Science (incl Cond Matter)
- ☐ Medical Applications
- ☐ Nuclear Physics
- ☐ Polymers
- ☐ Physics (Excl Condensed Matter)
- ☐ Instrument Development
- ☐ Neutron Physics
- ☐ Fission
- ☒ Reactions
- ☒ Spectroscopy
- ☐ Nuc. Accel. Reactor Eng.
- ☐ Def. Science/Weapons Physics
- ☐ Radiography
- ☐ Threat Reduction/Homeland Sec.
- ☐ Other:

FUNDING AGENCY

- ☐ DOE/BES
- ☐ DOE/OBER
- ☒ DOE/NNSA
- ☐ DOE/NE
- ☒ DOE/SC
- ☐ DOE/Other
- ☐ DOD
- ☐ NSF
- ☐ Industry
- ☐ NASA
- ☐ NIH
- ☐ Foreign:
- ☐ Other US Gov't:
- ☐ Other:

PUBLICATIONS

Publications:

See GEANIE publication list.

Abstract: S1523_gea-prop-XS-.pdf

By electronic submission, the Principal Investigator certifies that this information is correct to the best of their knowledge.

Safety and Feasibility Review *(to be completed by LANSCE Instrument Scientist/Responsible)*

☐ **No further safety review required** ☐ **To be reviewed by Experiment Safety Committee**

☐ **Approved by Experiment Safety Committee, Date:**

Recommended # of days:	**Change PAC Subcommittee and/or Focus Area to:**	**Change Instrument to:**

Comments for PAC to consider:

Instrument scientist signature: **Date:**

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Development of Neutron-Induced Gamma-Ray Reference Cross Sections
(Measurements of Photon Production Cross Sections for Ti and 7Li
Relative to Cr and Fe)

R.O. Nelson, M. Devlin, and N. Fotiades – LANSCE-NS, LANL

Accurate cross sections for neutron-induced gamma ray production are needed for a variety of applications. The 847 keV gamma ray excited in ^{56}Fe(n,n'γ) has been used as a reference cross section but suffers from a number of issues that limit the accuracy in its use. These issues include: (1) above the (n,p) reaction threshold the beta decay of ^{56}Mn to ^{56}Fe produces the same 847 keV gamma ray that adds to the measured cross section and is time dependent with a 2.6 hr half life, (2) iron is a common structural material in many experiments, the background from other components adds to the measured cross section, (3) the 847 keV cross section is not isotropic, thus the measured cross section depends on the angle of measurement. This is pronounced effect at low incident neutron energies.

The most accurate neutron-induced cross section data have uncertainties of about 5%. The 1434 keV gamma ray excited in ^{52}Cr(n,n'γ) is an example of one of the best determined cross sections. However, Cr is a difficult material from which to conveniently make samples due to the brittle nature of the metal. Cr also has (n,p) reaction and angular distribution problems like those mentioned for Fe above. It is desirable to create reference cross sections for neutron-induced gamma-ray cross sections that have better properties if possible.

There are a variety of properties desired in a useful neutron-induced gamma-ray cross section reference. These properties include:

(1) a relatively large cross section to maximize signal to background and to keep measurement times short
(2) relatively constant cross section with energy so that small changes in energy do not result in significant changes in the measured value
(3) isotropic gamma-ray angular distributions so that measurements are independent of angle
(4) sample material that can be purchased and fabricated into a desired form with good uniformity at reasonable cost and without adverse health or environmental consequences. These materials will be mono-isotopic or nearly so to keep the cost low and the observed signal large.
(5) having gamma rays that are free from time-dependent feeding such as that from beta decay (from products produced in (n,p) reactions) or from long-lived isomers in the excited nucleus.
(6) having gamma rays with energies that are well separated from common background gamma rays (in neutron experiments) and that preferably are in regions of low background
(7) useful for neutron-induced cross section measurements with both "white source" neutrons and mono energetic neutron sources. Both few MeV and 14 MeV

incident neutron energy reference cross sections are needed, as well as higher energy reference cross sections

From an examination of previously measured neutron-induced gamma-ray cross sections we have identified issues with many gamma-rays from materials commonly used as reference cross sections. Often these gamma-rays were chosen because of convenience, such as in the case of Fe, however the experimental record shows that there is little consistency in the measurements often presumably due to failure to account for some of the effects embodied in (1) – (6) above. In 2009 we identified some nuclides that have received little study in the past, but that might provide superior neutron-induced reference cross sections. In 2009 we studied Nb, In and Au but found problems such as previously unknown isomeric states and overlap with nearby gamma-ray lines that made them unsjuitable as rerference cross sections. However, based on the GEANIE data of D. Dashdorj on Ti and its properties we now favor Ti as a good reference cross section. In addition, we have reexamined 7Li as a reference cross section for energies below 1 MeV. In inelastic scattering on 7Li the isotropic 478 keV gamma ray is produced with a reasonly good cross section.

We propose to measure relative and absolute cross sections for gamma rays produced in the neutron bombardment of Ti and 7Li relative to ^{52}Cr and ^{56}Fe as part of an effort to improve the gamma-ray reference cross sections available. This effort aids in improving the accuracy of all neutron-induced gamma-ray measurements. Both inelastic and (n,2n) product gamma rays have been identified that will provide reference cross sections at both few-MeV and 14-MeV incident neutron energy.

Ti metal and Li (carbonate or fluoride) will be irradiated simultaneously with Cr to obtain relative cross sections for the strong gamma rays of interest. Cr appears to have one of the most accurately determined cross sections and thus is being used as a reference cross section. Absolute measurements using ^{238}U and ^{235}U fission foils will also be performed. Fission cross sections for both uranium 235 and 238 are primary cross section standards. The goal is to develop new reference cross sections that have good gamma-ray intensity and provide readily available and clean samples. The most suitable Li compound and determination of the isotopic content will be addressed.

This work builds on previous measurements using GEANIE on WNR flight path 4FP60R. With ~3mm thick metal foils and 40 Hz beam delivery to WNR we estimate that approximately 10 days per sample are needed to achieve the desired < 5% statistics for few % incident neutron energy bins using GEANIE with 9 planar Ge detectors and the remainder coaxial detectors.

Below we show data already acquired on ^{48}Ti with GEANIE. The Ti data served as the dissertation work of D. Dashdorj of North Carolina State University.

The ^{48}Ti(n,n'γ) cross section is similar to the Fe cross section, but ^{48}Ti has advantages over Fe because the production and feeding of the 983 keV gamma ray following the (n,p) reaction is greatly reduced compared to that for ^{56}Fe, and Ti is not typically found in appreciable amounts in the structural and other components of gamma-ray detector arrays, thus not contributing backgrounds that would interfere with the cross section measurement.

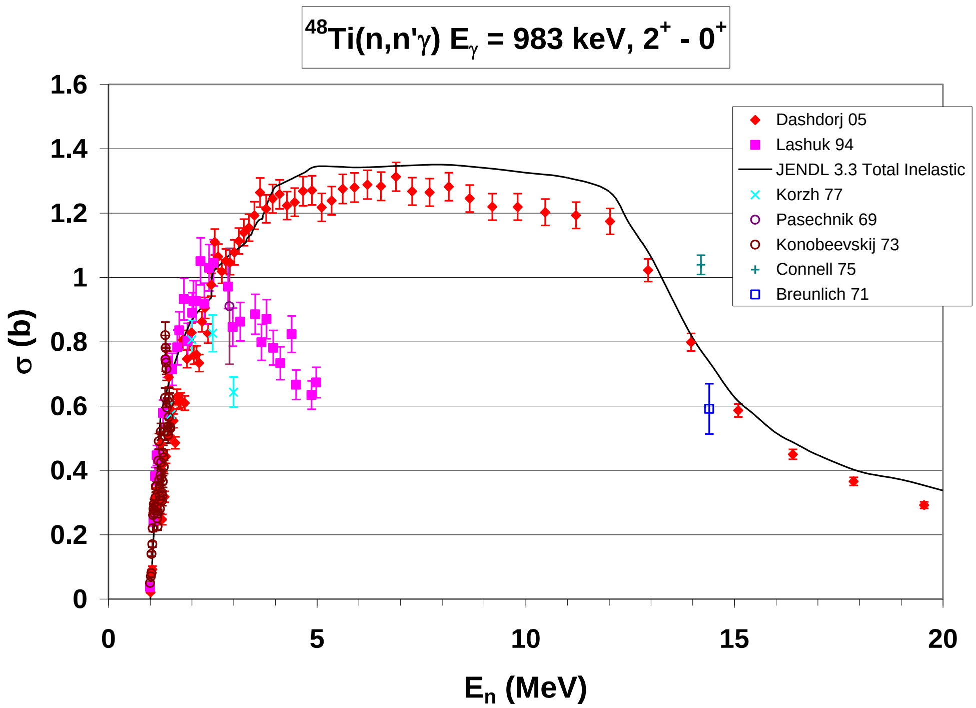

Fig. 1 Data for ^{48}Ti(n,n'γ) are shown in barns for the 983 keV gamma ray. These are recent GEANIE data (red points) that show the potential for using this gamma ray as a reference cross section from 4 to 14 MeV. More accurate relative cross section measurements are needed to improve the accuracy with which this cross section is known.

To confirm our measurements, we plan to work with staff at the IRMM, GEEL, Belgium and TUNL, North Carolina, USA to make additional measurements on these materials, based on the results of our studies. The ultimate goal is to have reliable reference cross sections in the few MeV and 14 MeV incident neutron energy regions that are easy to use and with accuracies better than 5%. This goal is supported by the IAEA International Nuclear Data Committee as reported in the proceedings of a recent Consultants Meeting (INDC(NDS)-0540, Nov. 2008).